

**Upwelling conditions and cohort analysis of  
the euphausiid *Euphausia pacifica*  
off Newport, OR, USA**

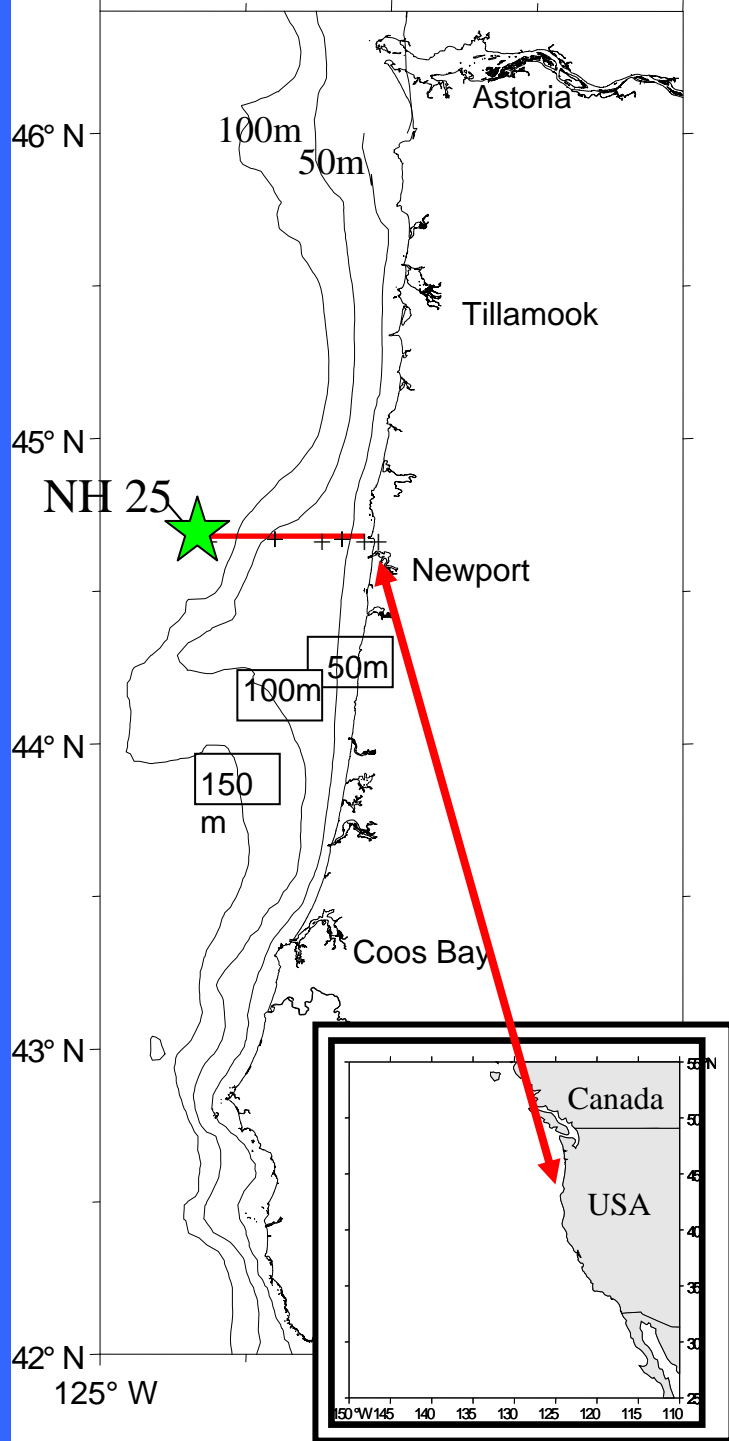


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# Background & Objectives

- *Euphausia pacifica* have a period of intense spawning activity July-August in our study area. Using biweekly samples, could we:
  - Identify a cohort attributable to this intense summer spawning activity
  - Track a cohort over time
  - See interannual variability in cohorts in relation to upwelling conditions
  - Compare cohort growth rates to growth rates measured in live animal experiments
  - Create survivorship curves

# Time series off Newport, OR (NH line)



- Sampled twice per month by the Peterson lab since 1996
- Adult euphausiids sampled with night bongo tows starting in 2001
- Cohort data from station NH25 (★) at the shelf break (~300m)
- Instantaneous growth rate (IGR) experiments on live animals since 2001

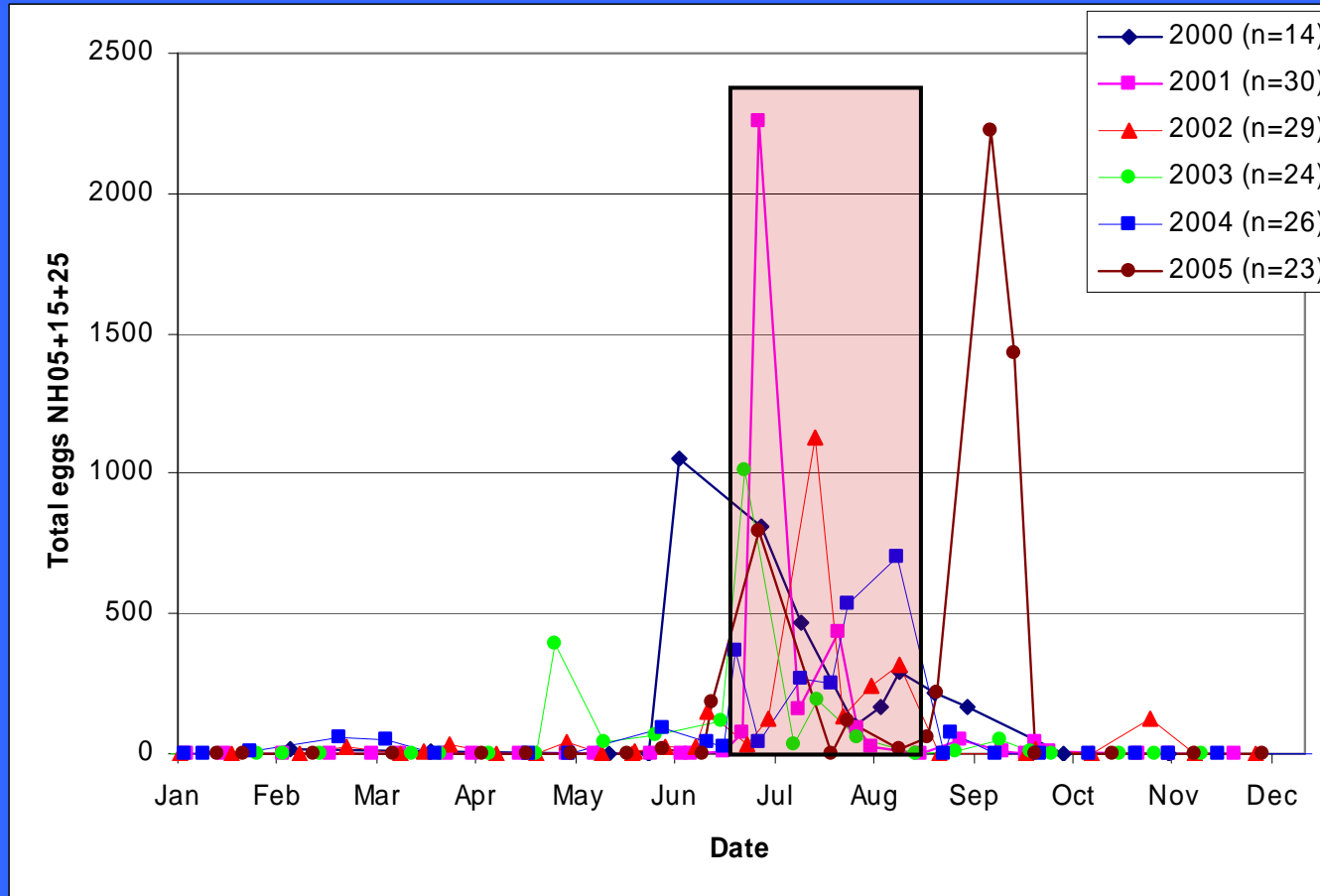
# Methods

- Counted euphausiid eggs from 1/2m vertical net samples to determine timing of high egg density (“egg peak”)
- Counted and measured juvenile and adult *E. pacifica* from nighttime bongo nets
- Identified cohorts using maximum likelihood method in Matlab
- Characterized upwelling conditions for each year based on timing and intensity
  - Timing: Logerwell et al. 2003 and [http://www.cbr.washington.edu/data/trans\\_data.html](http://www.cbr.washington.edu/data/trans_data.html)
  - Intensity: Cumulative upwelling from <http://www.pfel.noaa.gov/products/PFEL/modeled/indices/upwelling/upwelling.html>

# Cohort Identification

- Cohorts are based on juveniles and adults since larvae are rarely present in sufficient numbers to identify a cohort
- *E. pacifica* develop from egg to juvenile in an average of 60 days (Feinberg et al. 2006).
- Therefore, a cohort that appears about two months after an egg peak could be attributable to those eggs

# *E. pacifica* spawning activity



# Upwelling and Euphausiid Eggs

Year	Spring transition (ST)	Fall transition (FT)	Duration of upwelling (mo)	CUI	ST→ egg peak (mo)
2001	2-Mar	12-Nov	8.5	6642	4.6
2002	21-Mar	6-Nov	7.7	7611	4.1
2003	22-Apr	15-Oct	5.9	7940	2.4
2004	20-Apr	7-Nov	6.7	4800	4.0
2005	25-May	29-Sep	4.2	5906	4.0
2006	22-Apr	31-Oct	6.4	9747	--
<b>Averages</b>			<b>6.7</b>	<b>7108</b>	<b>3.8</b>

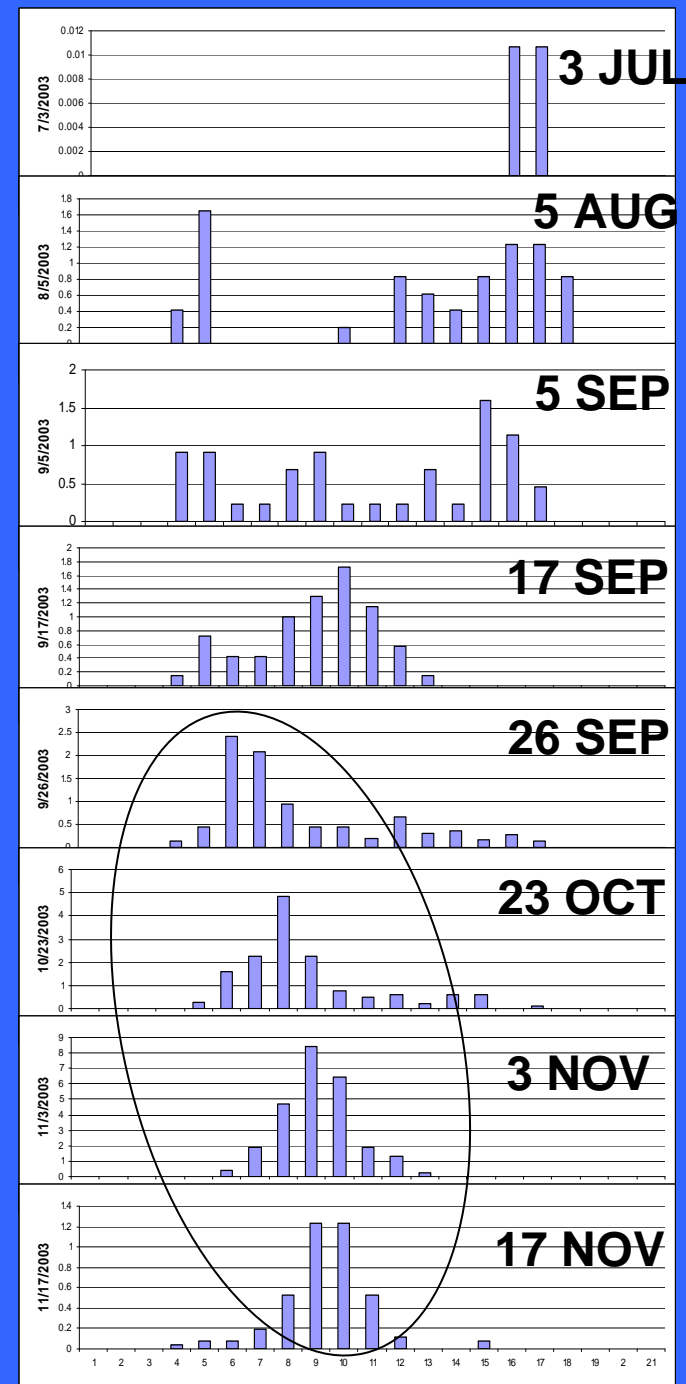
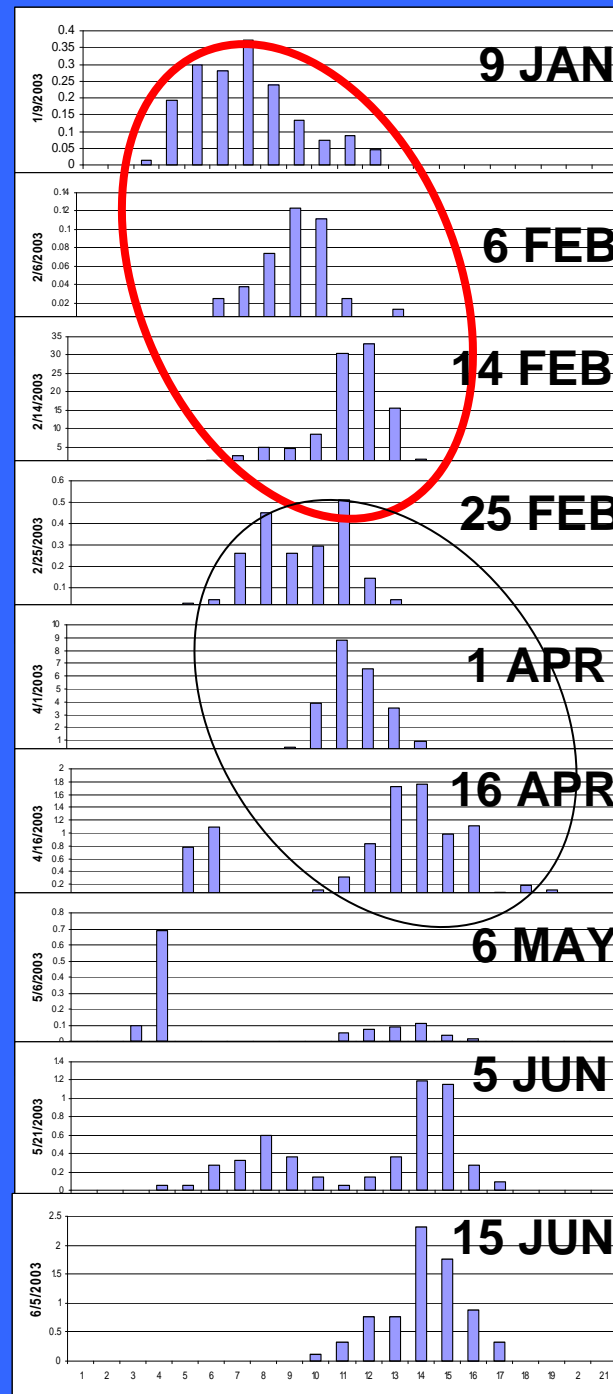
# “Traditional” cohort analysis

- Adult and juvenile *Euphausia pacifica* counted and measured from biweekly samples
- Plotted for each sampling date in 1 mm length bins
- The next slide shows the cohort data from 2003

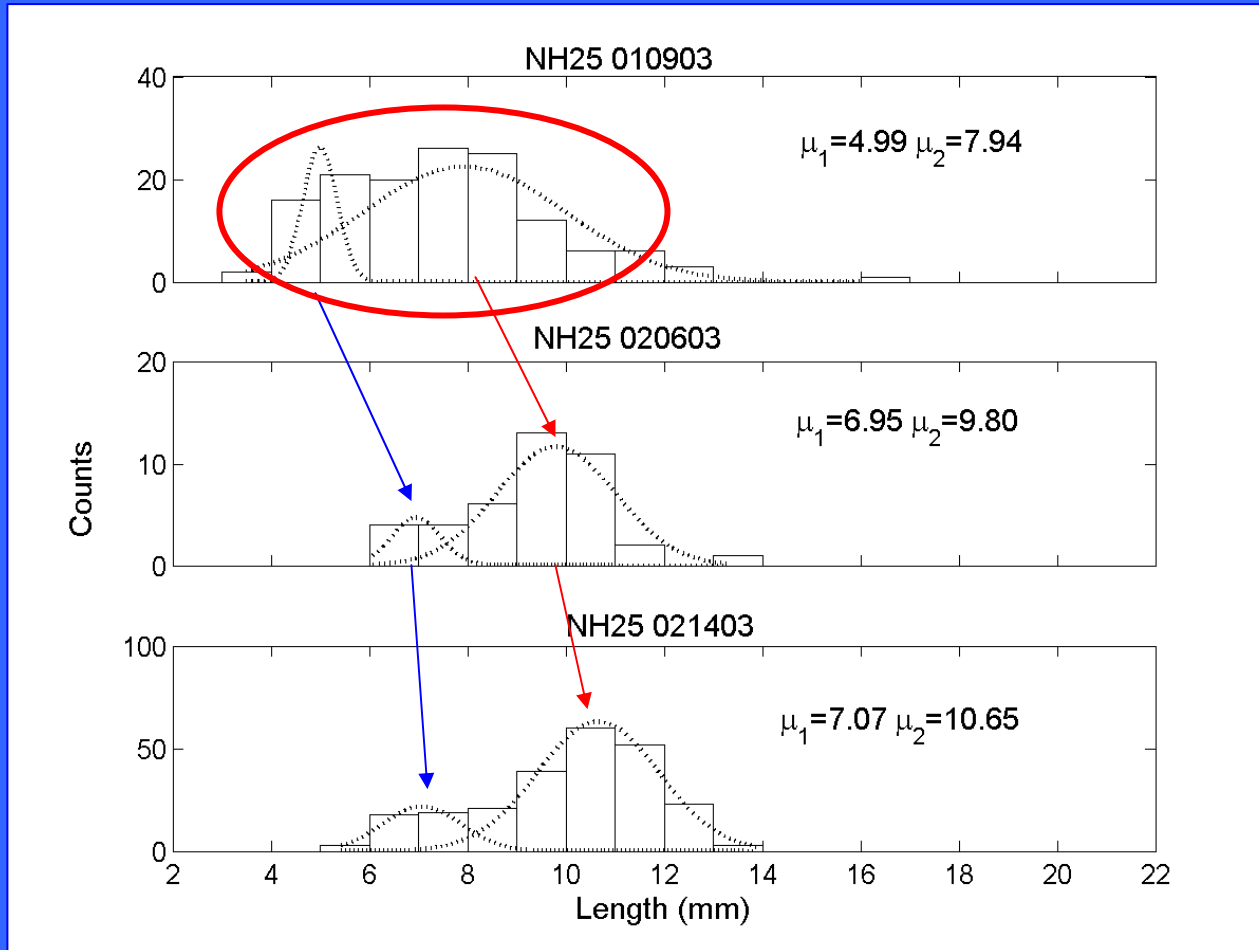
# Cohort Data 2003

We can calculate  
growth rates from  
change in cohort  
mean length over  
time.

Traditional cohort  
analysis  
subjective with  
size modes  
identified by eye.

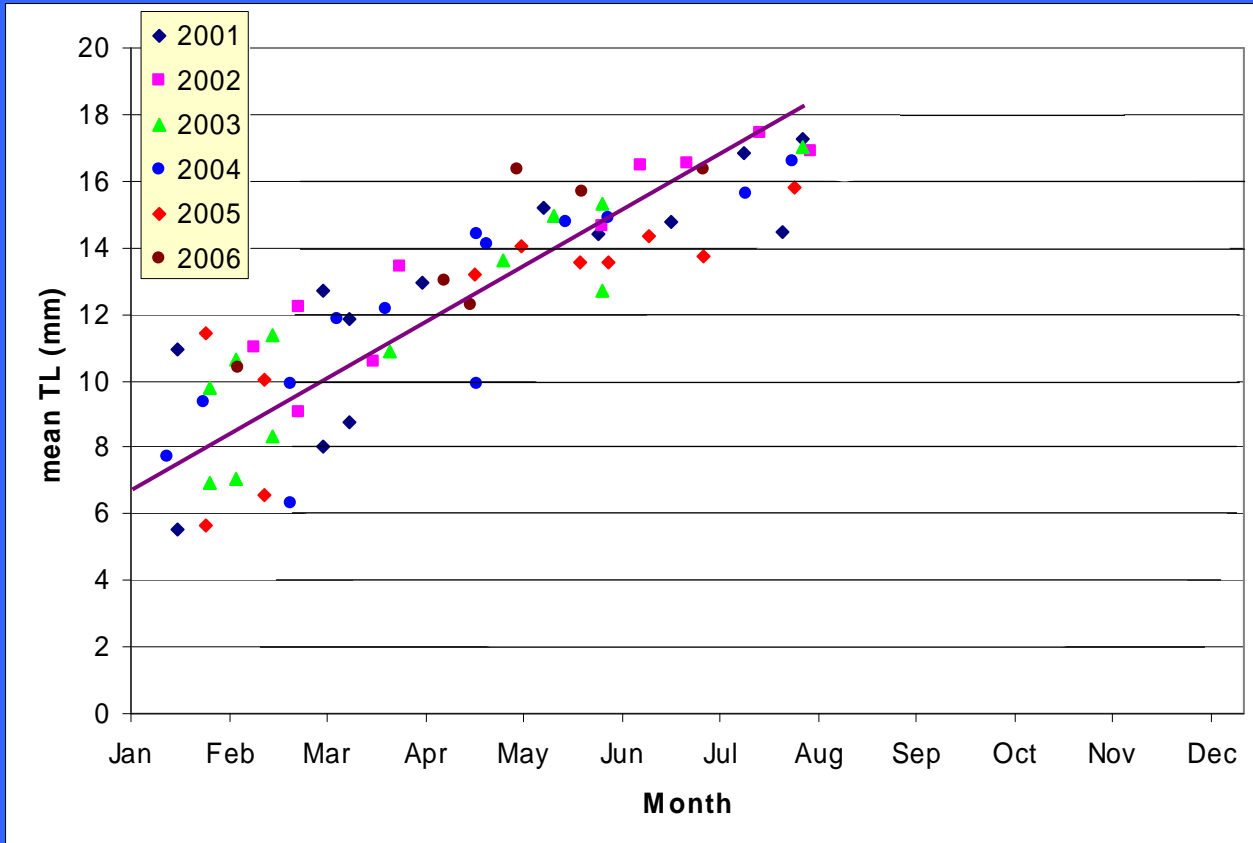


# Cohorts from maximum likelihood method



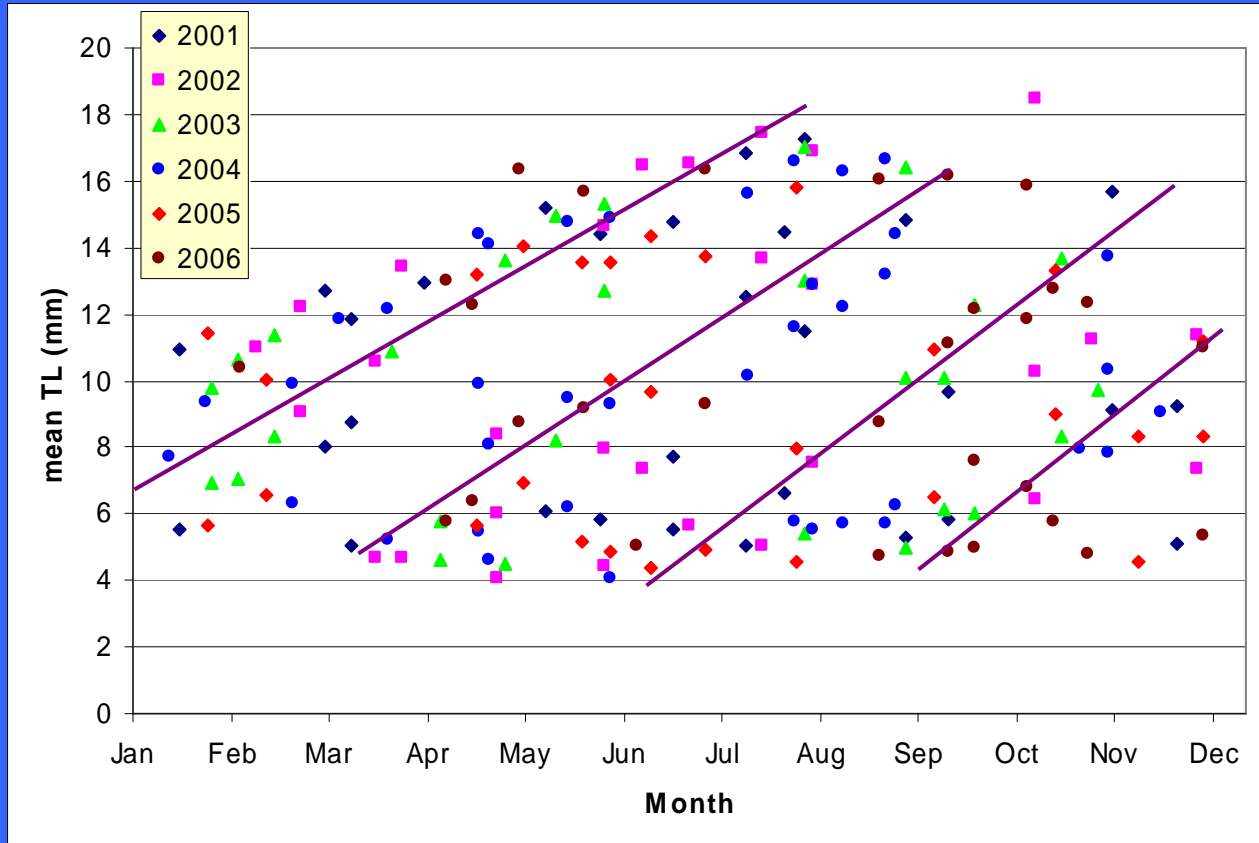
- This technique identifies overlapping distributions
- We calculated growth rates from change in mean length of each size mode from one sampling date to the next

# Cohort mean TL 2001-2006



- Cohort appears in Jan/Feb time frame in all years
- November spawning?
- Overwintering juveniles?

# Cohort mean TL 2001-2006



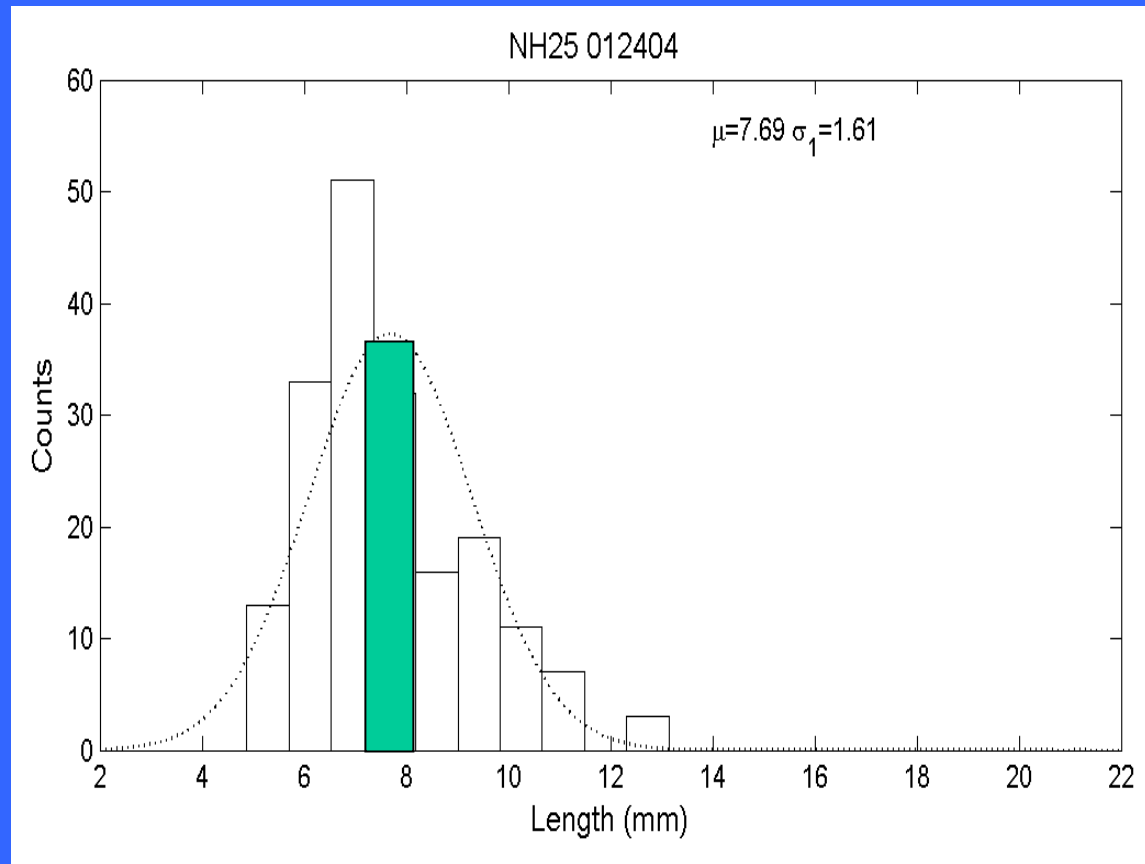
Cohorts start approximately:

- February
- April
- July
- September

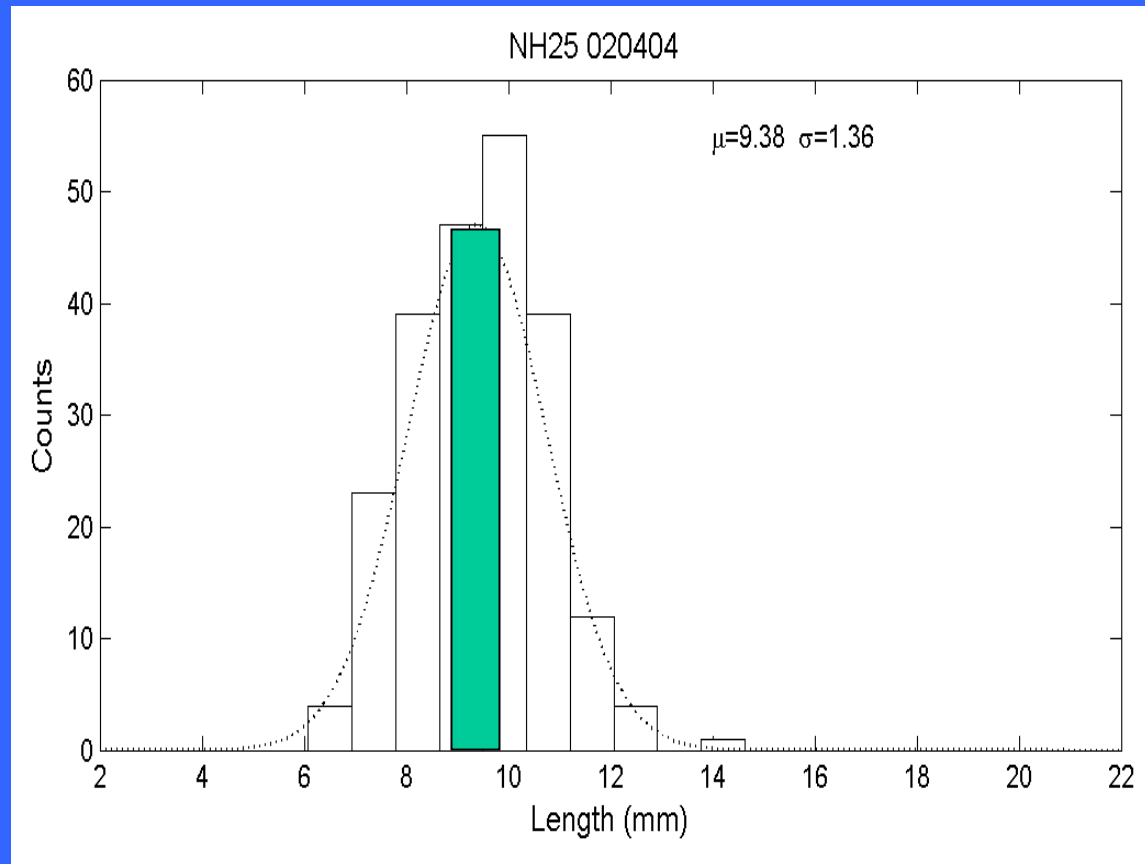
# Can we track a cohort?

- Previous slide showed that a cohort appeared in February of each year
- Attempted to track cohort through the year, using 2004 as an example
- February 2004 cohort shown in green in the following graphs
- New cohort appears in March (red bar)
- Another new cohort appears in May (blue bar)

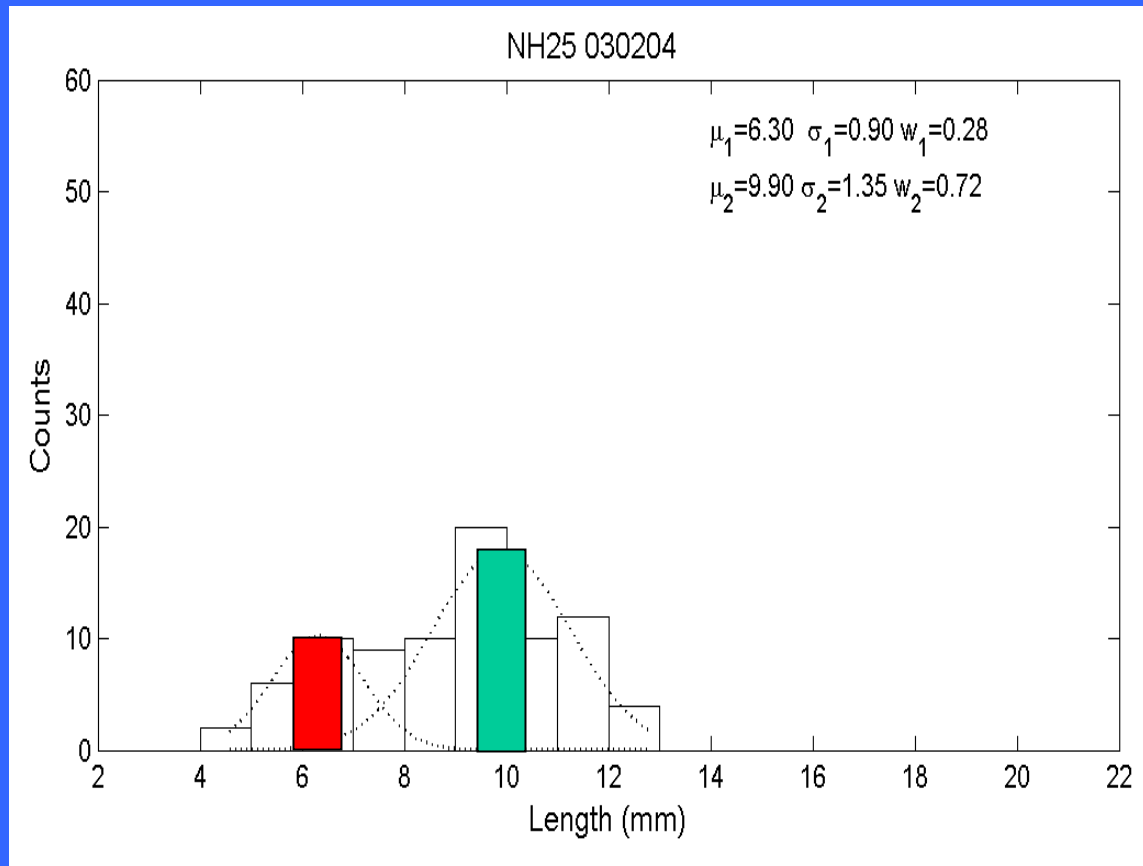
# 24-Jan



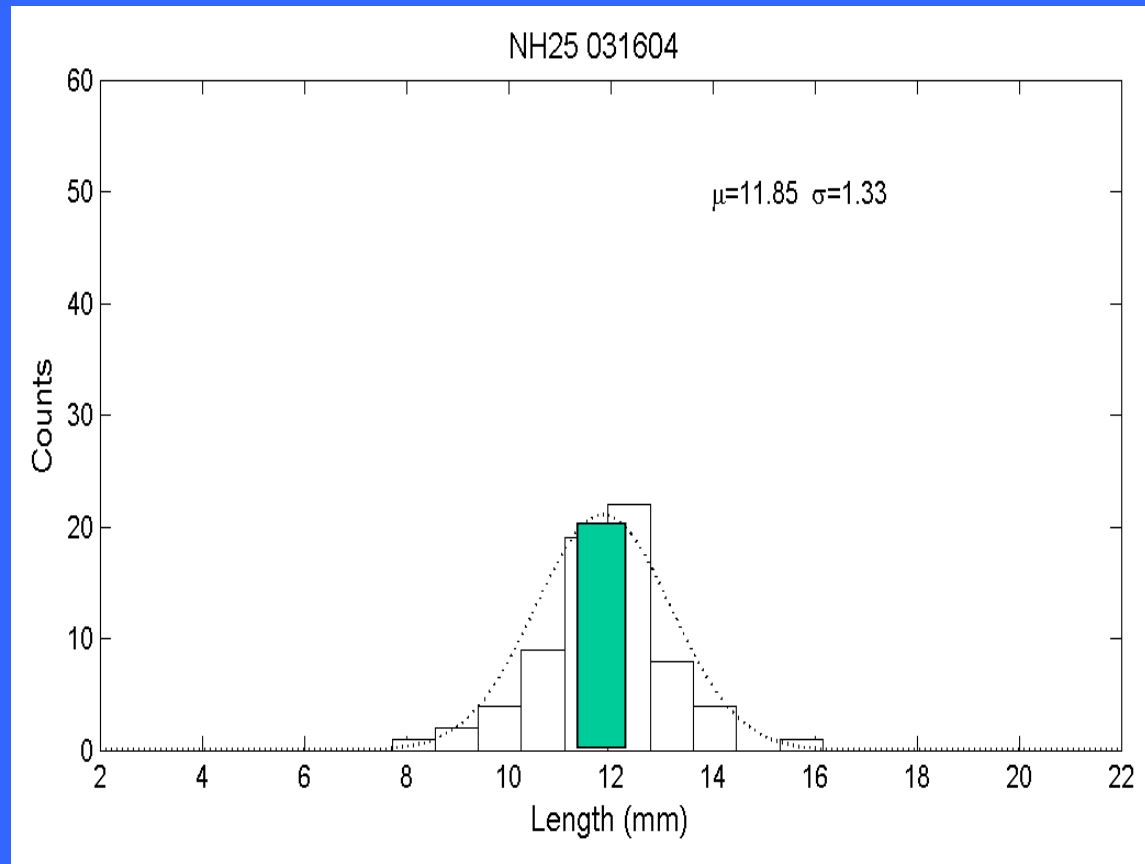
# 4-Feb



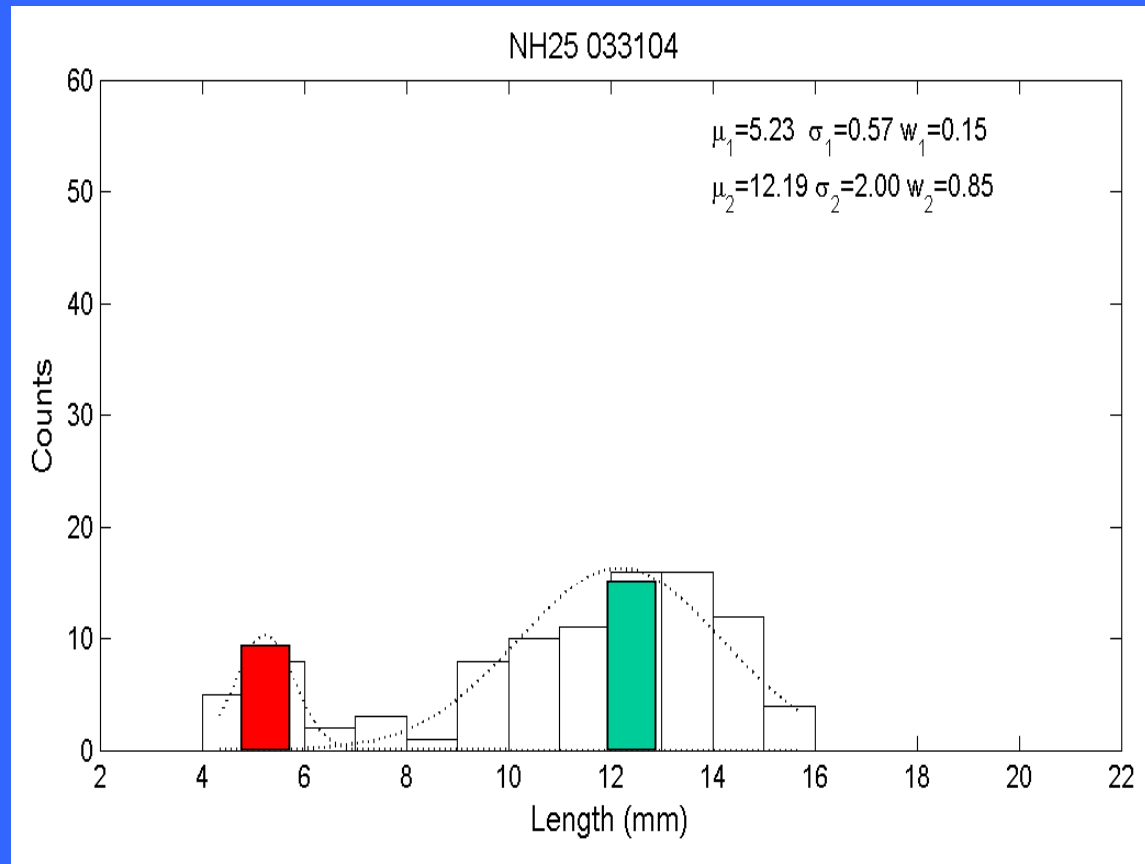
# 2-Mar



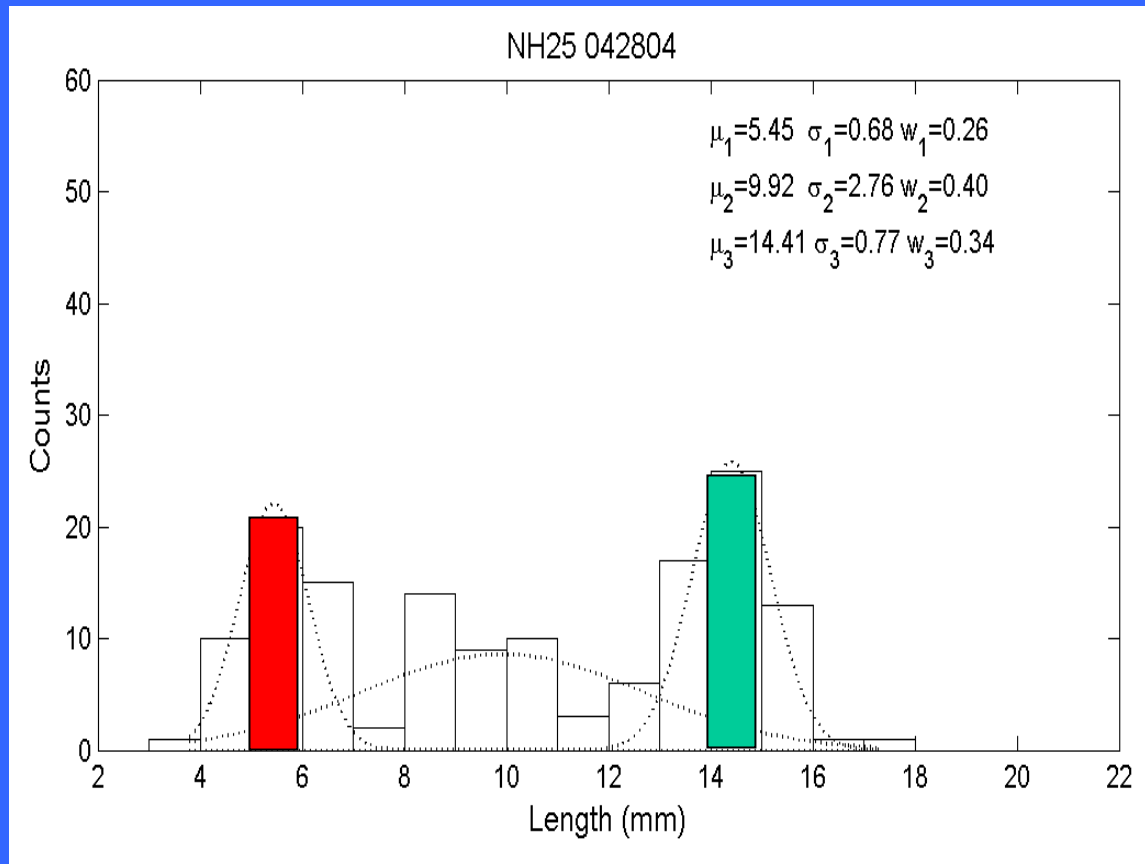
# 16-Mar



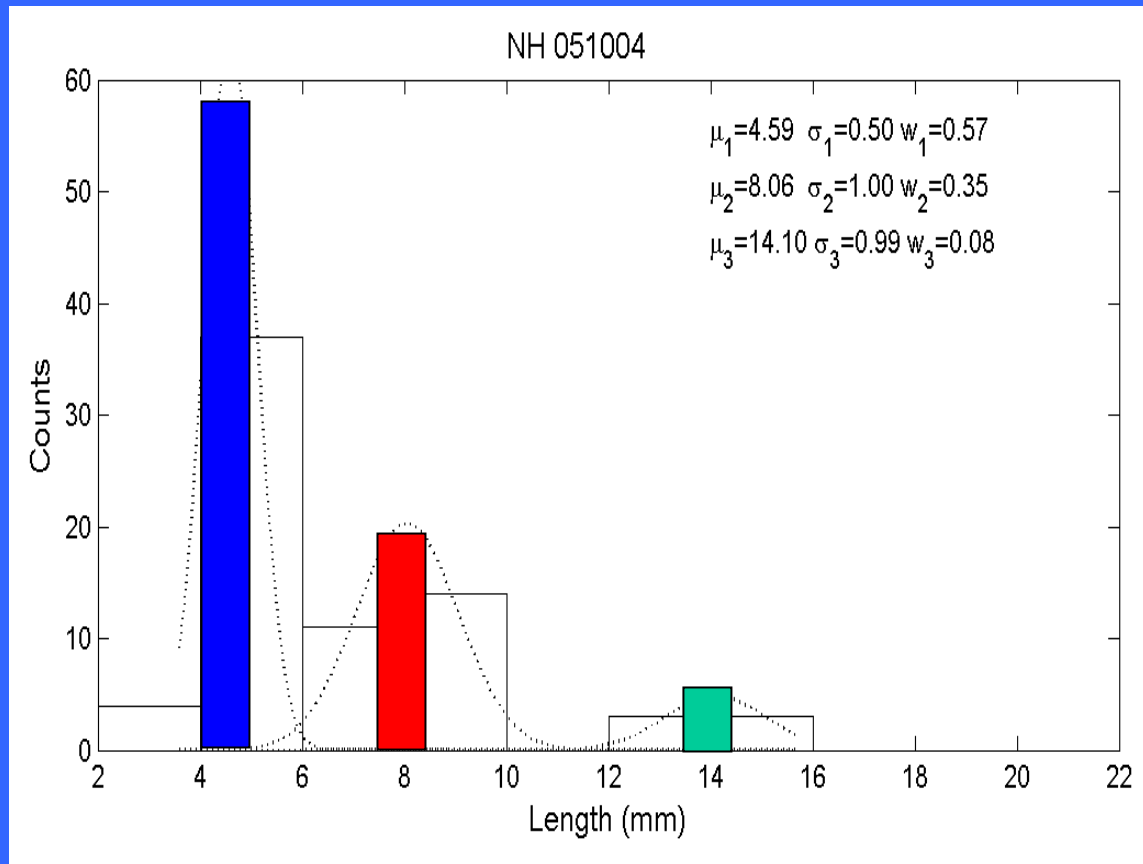
# 31-Mar



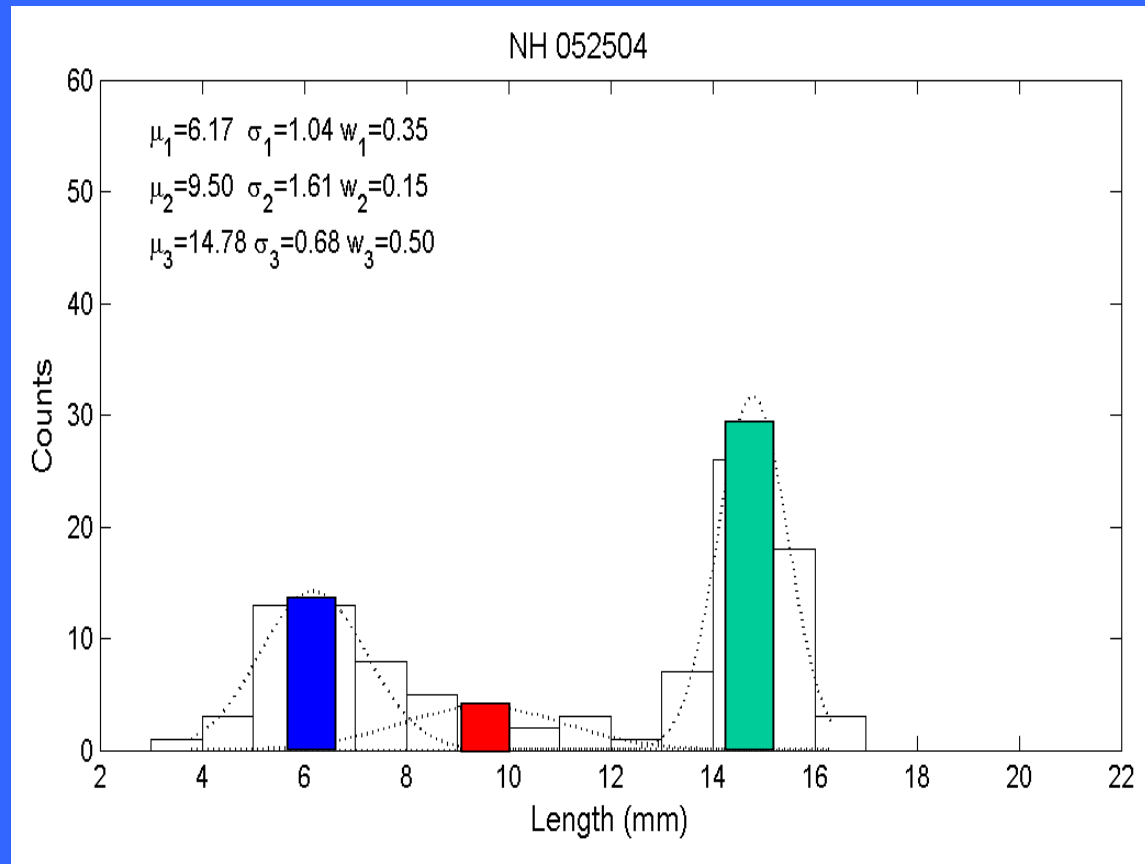
# 28-Apr



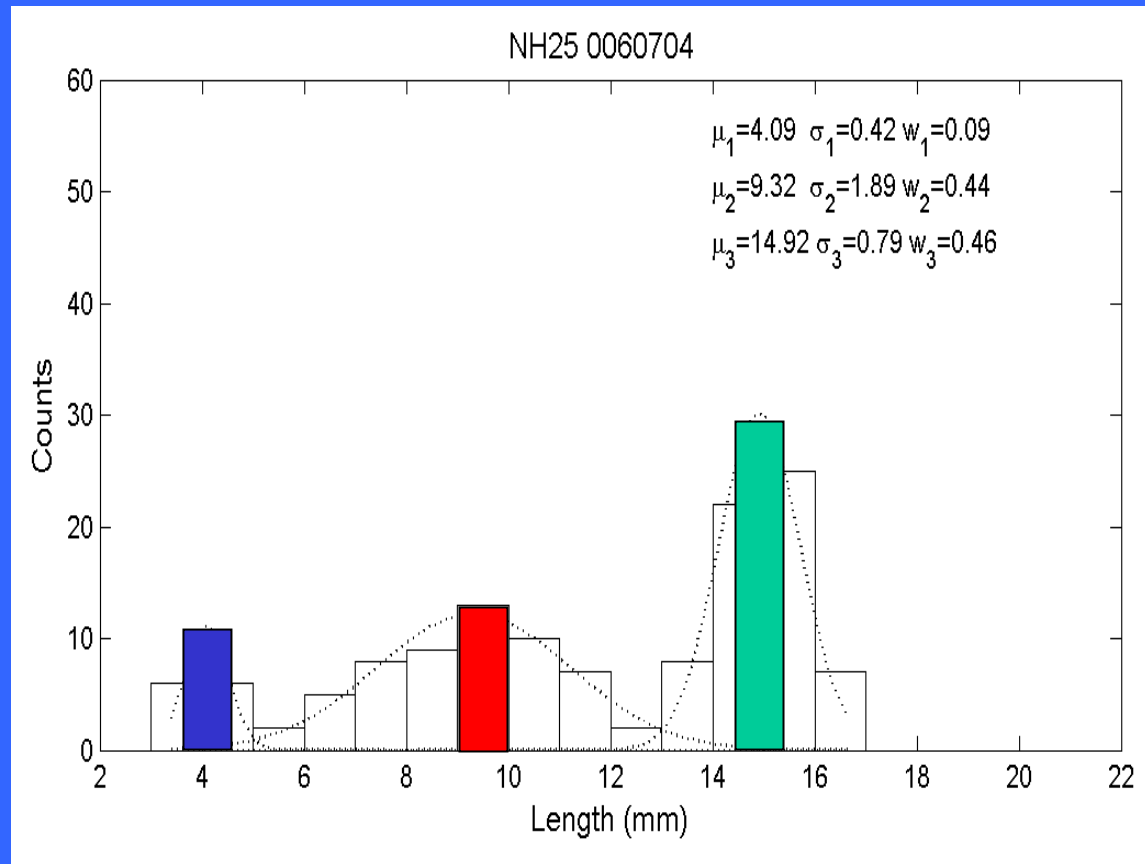
# 10-May



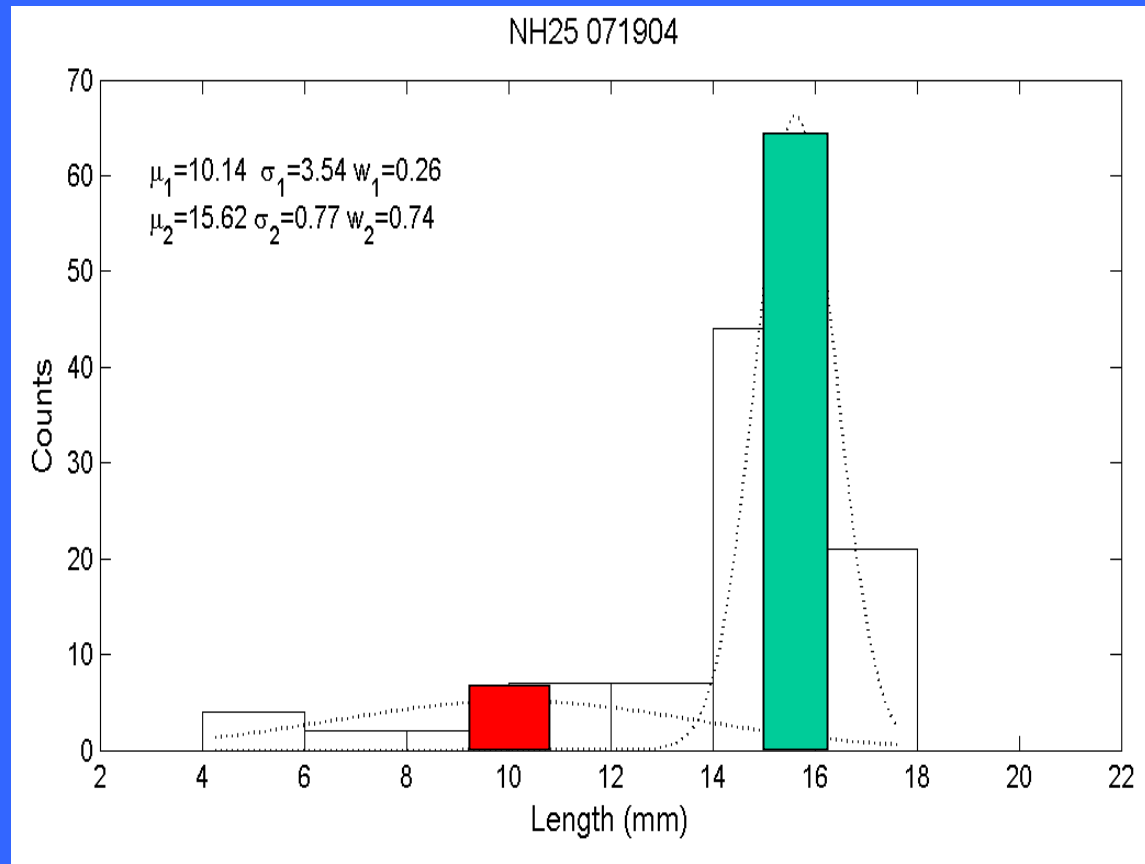
# 25-May



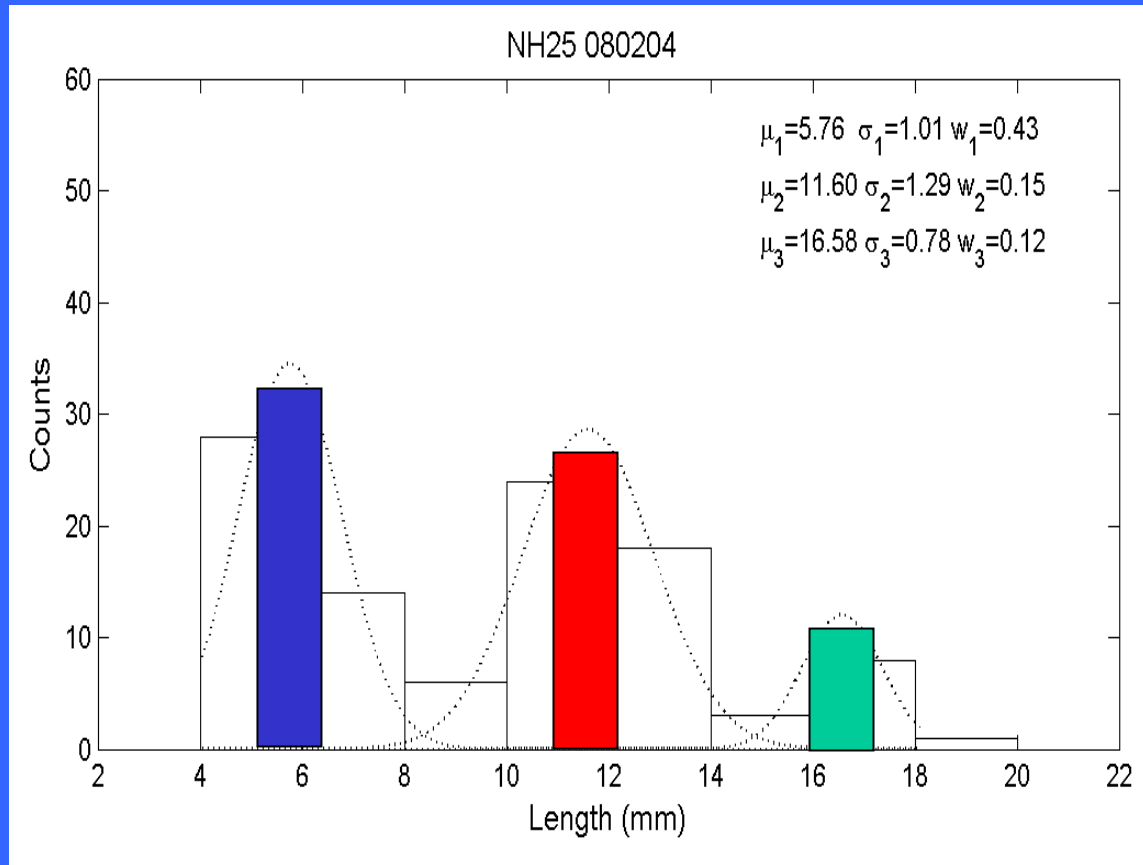
# 7-June



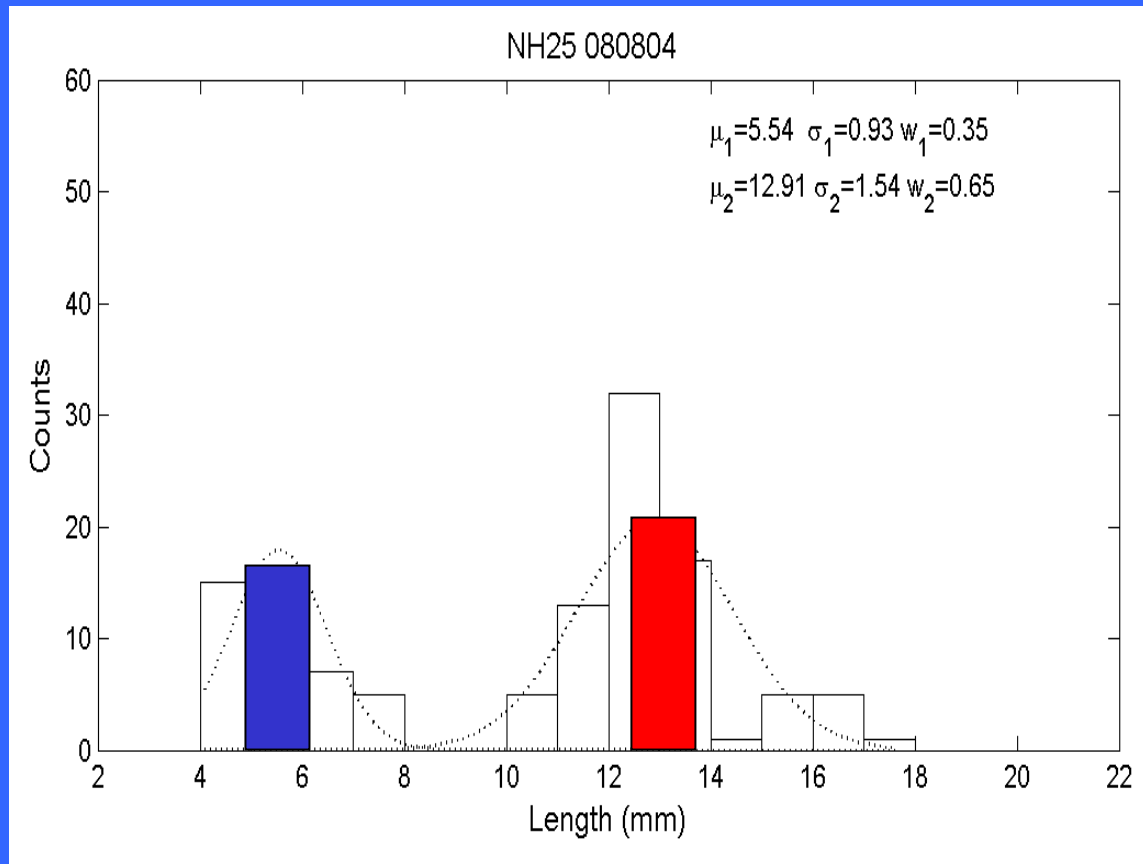
# 19-July



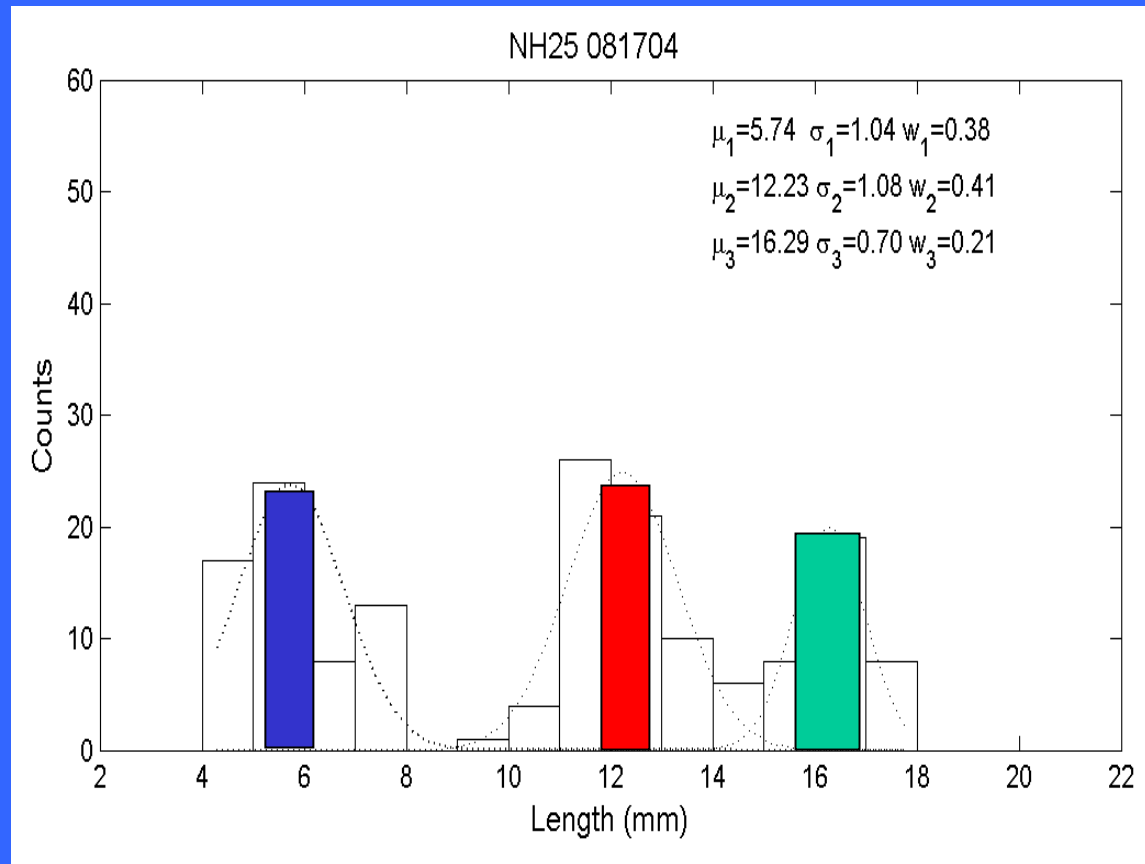
# 2-Aug



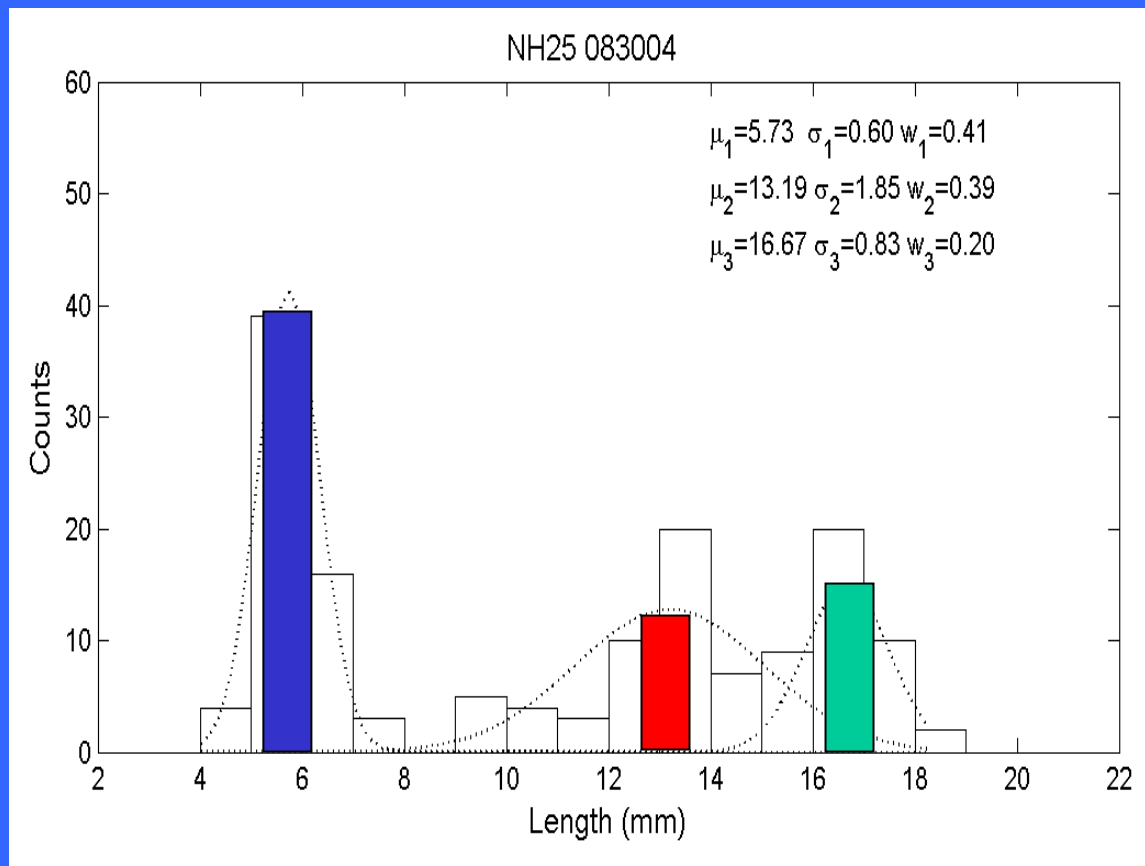
# 8-Aug



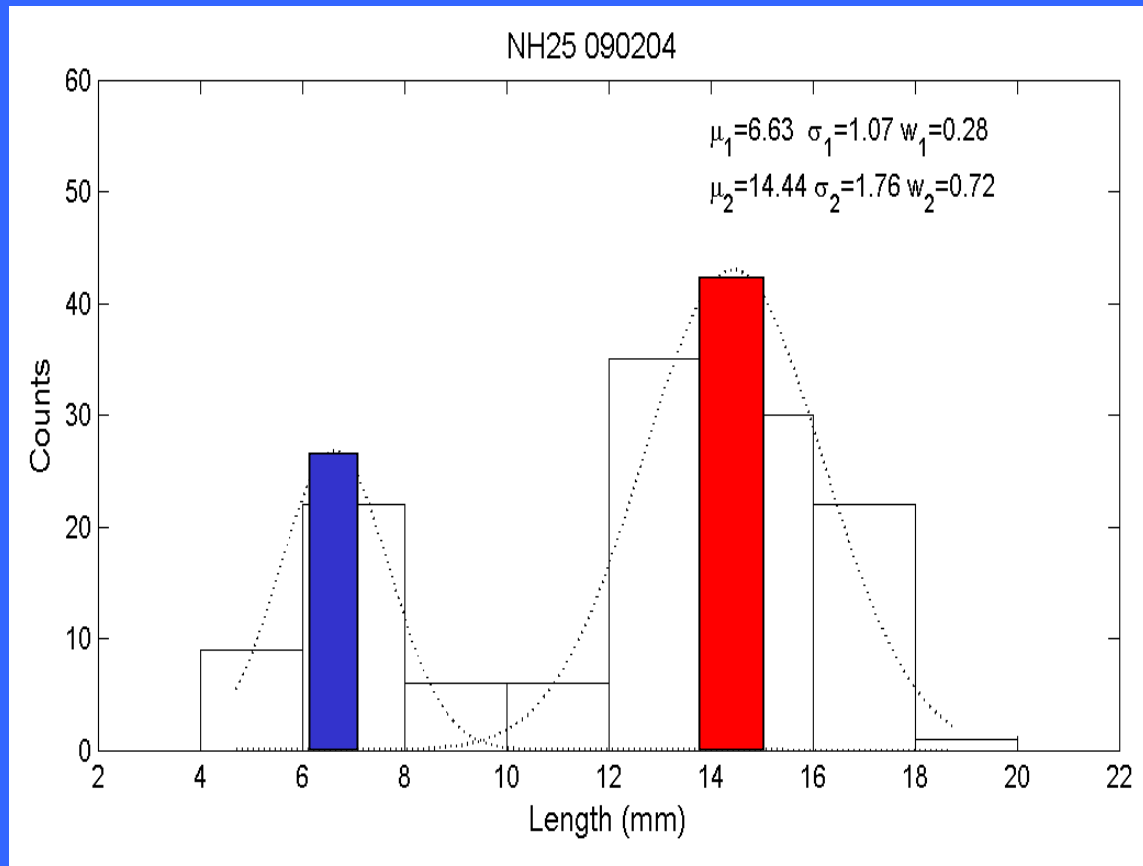
# 17-Aug



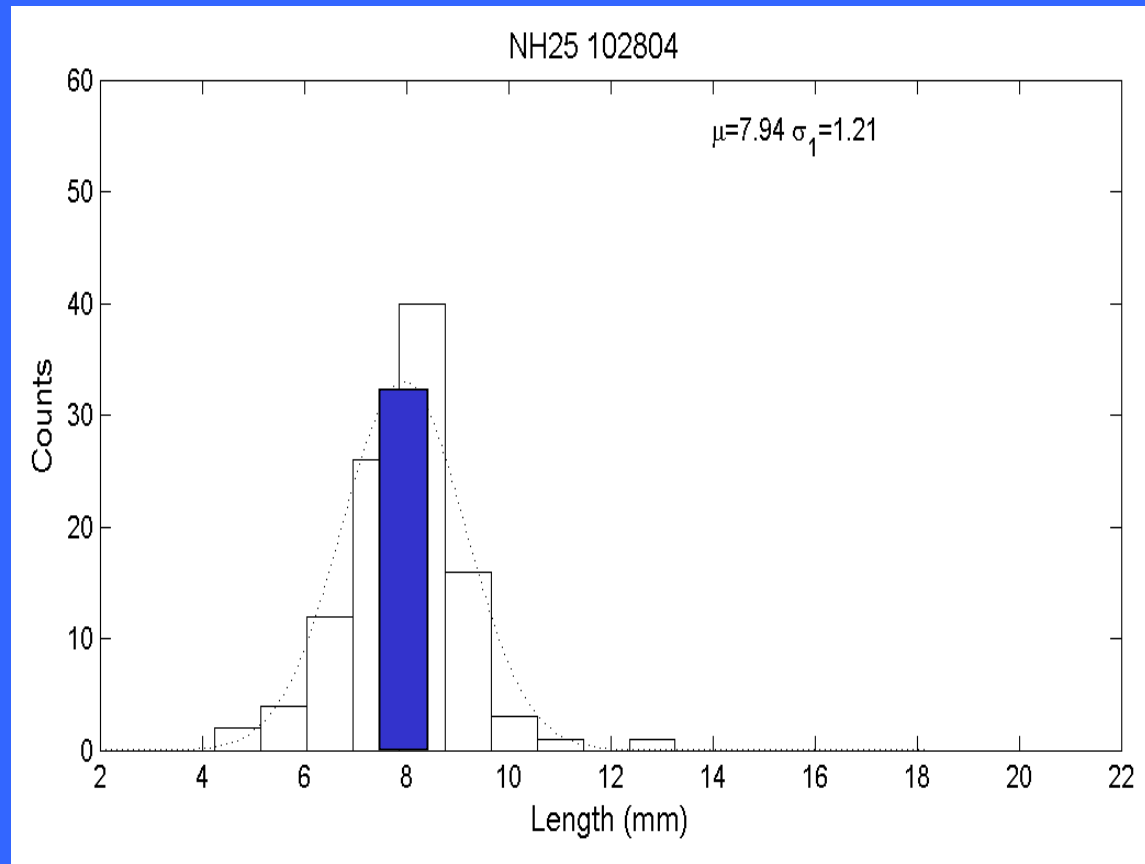
# 30-Aug



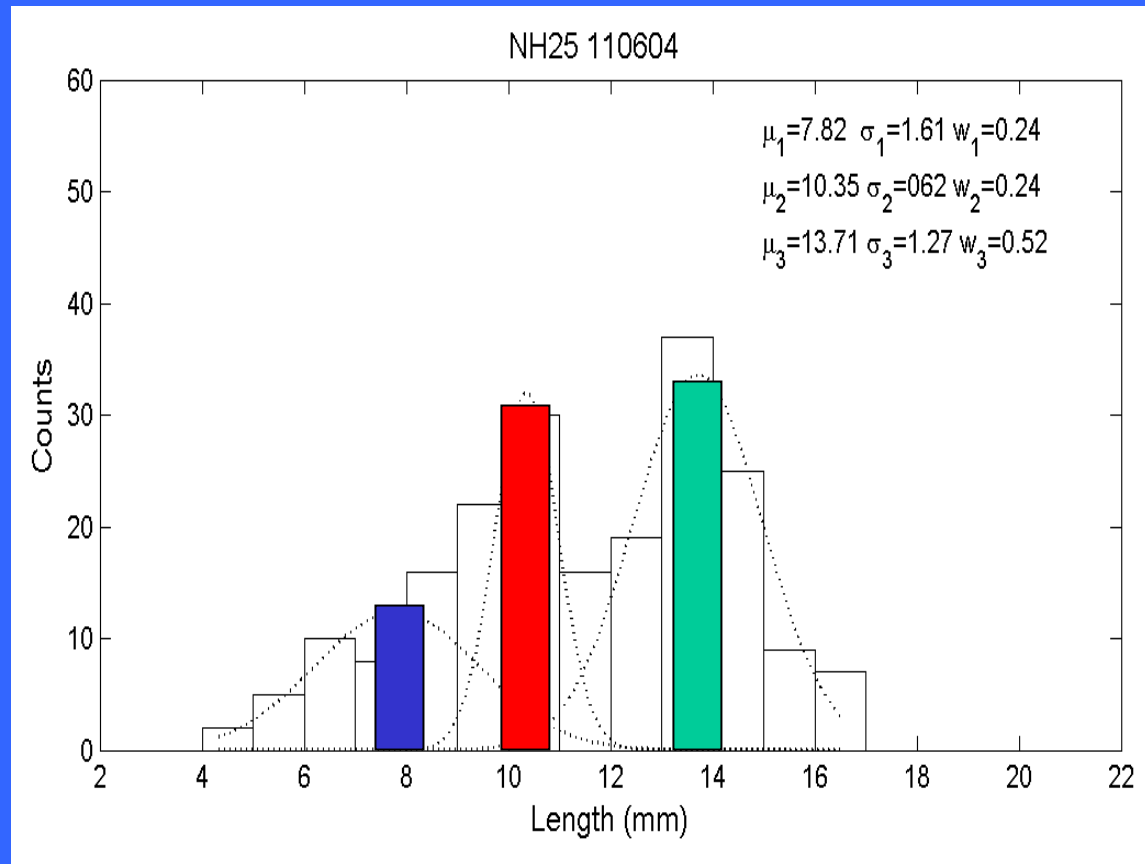
# 2-Sept



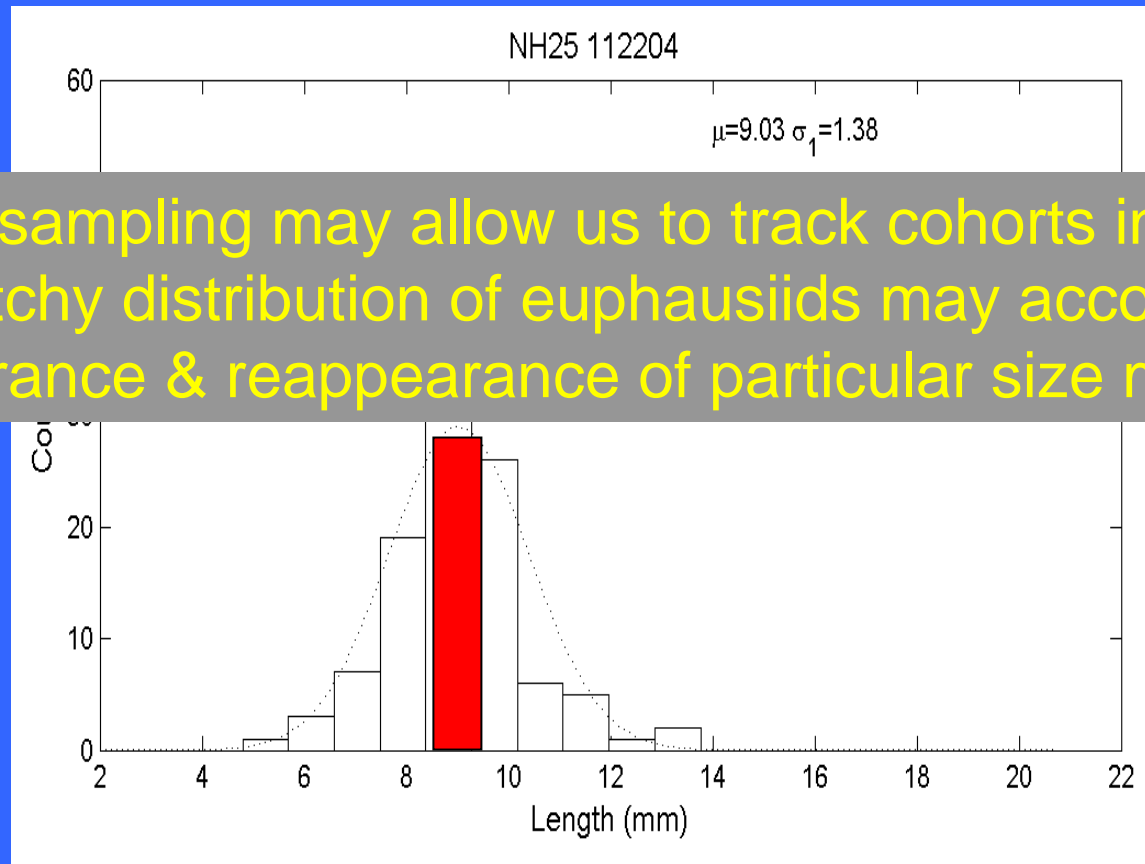
# 28-Oct



# 6-Nov



# 22-Nov



Biweekly sampling may allow us to track cohorts in our study area. Patchy distribution of euphausiids may account for disappearance & reappearance of particular size modes.

# Do juveniles appear ~2 months after egg peak?

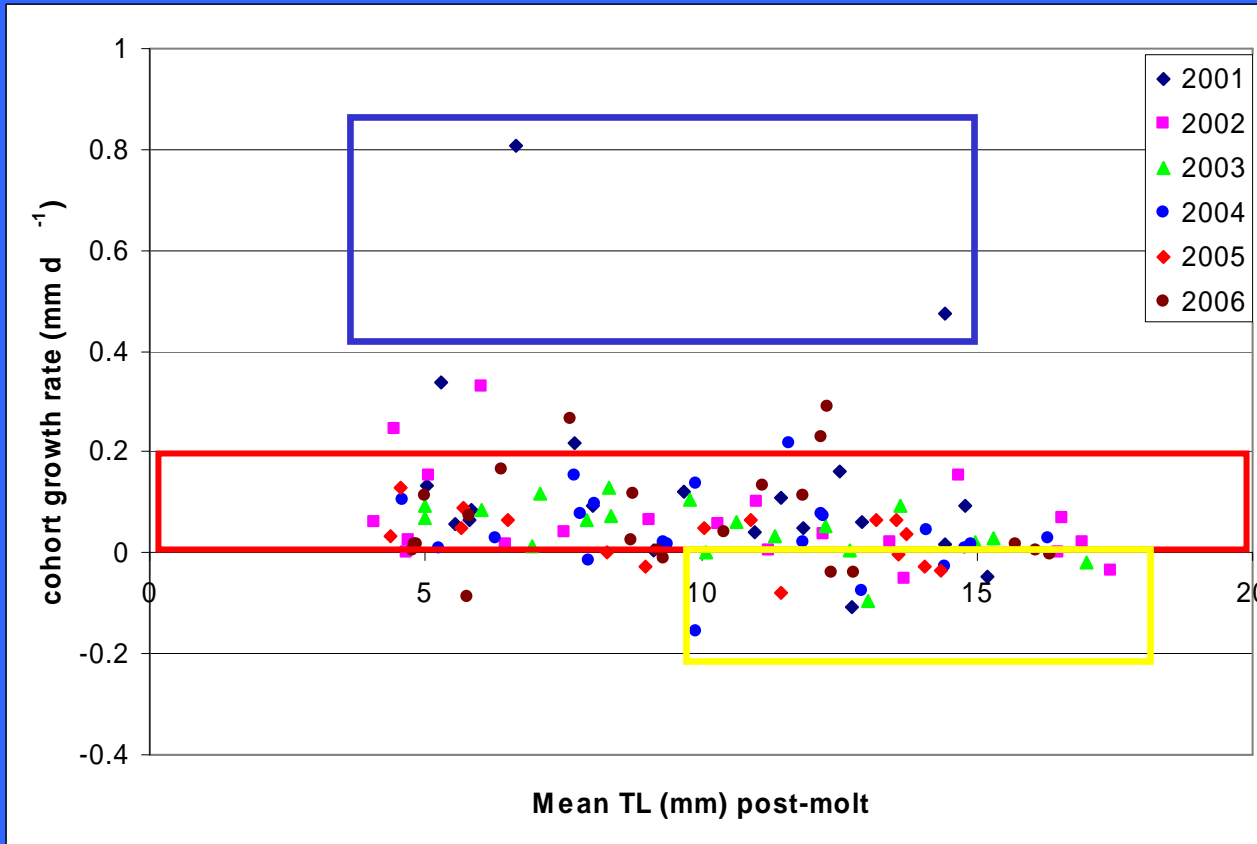
Year	Date of egg peak	Date size mode appeared	Months btwn dates	Size mode
2001	18-Jul	7-Nov	3.7	9.14
2001	18-Jul	27-Nov	4.4	5.13
2002	23-Jul	15-Oct	2.8	6.45
2002	1-Nov	6-Feb	3.2	6.95
2003	3-Jul	5-Sep	2.1	4.98
2004	17-Aug	28-Oct	2.4	7.95
2005	21-Sep	15-Nov	1.8	4.55
2006 ST: April 22		20-Oct	2.0	5.75

Test of this idea limited by sampling intervals. Longer intervals tend to have a higher size mode, consistent with the animals having had more time to grow.

# Growth rates: cohorts & experiments

- Growth rate calculated from change in mean length of cohort between sampling dates
- Individual krill may grow, shrink, or remain the same size after molting
- Molt approximately every 7 days in our study area
- Two-week sampling interval probably covers at least two intermolt periods
- Individual animals could grow and shrink within one sampling interval

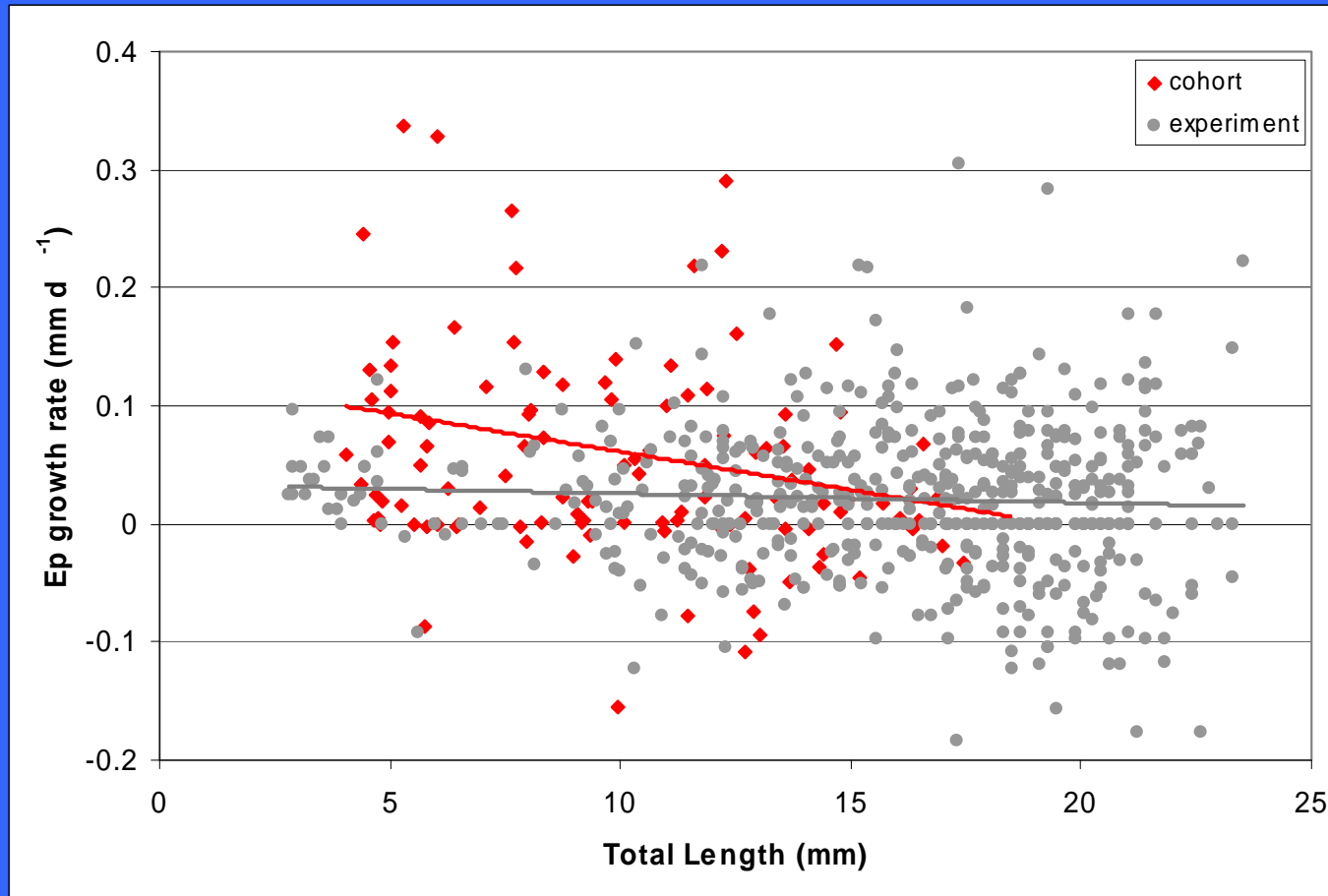
# Interannual variability in cohort growth



- Growth rates usually 0.01-0.17 mm d<sup>-1</sup>
- Growth rates above 0.4 mm d<sup>-1</sup> only in 2001
- Growth rates usually positive, negative growth more common when animals ≥10 mm

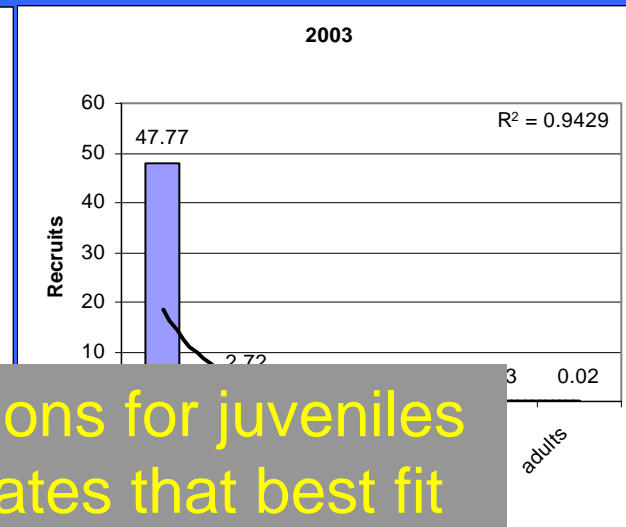
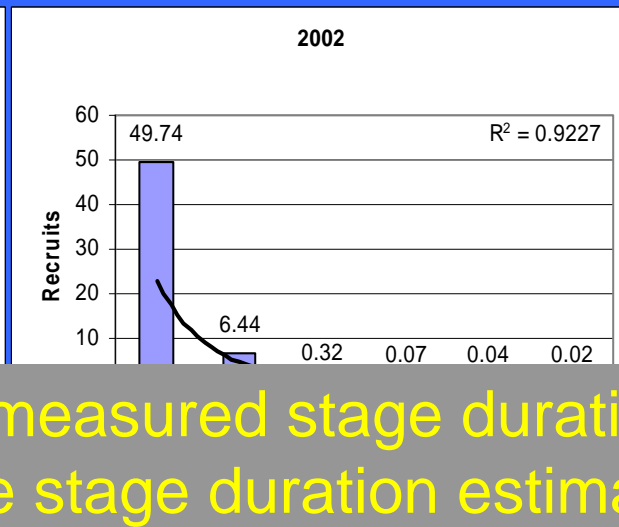
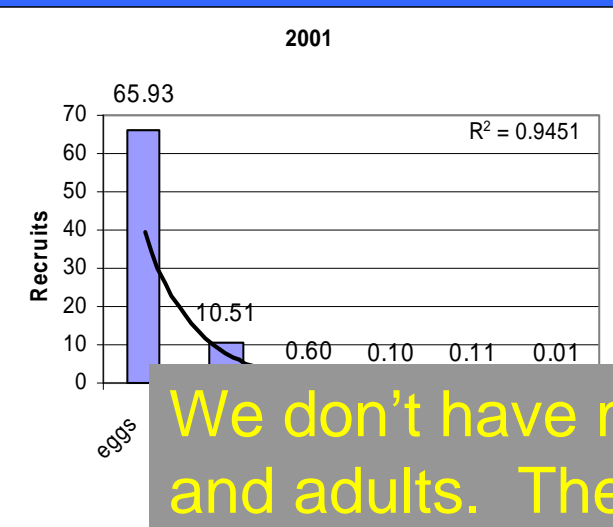
Cohort growth rates consistent among years.  
Interannual variability minimal if at all.

# Cohort and IGR (expt) growth rates



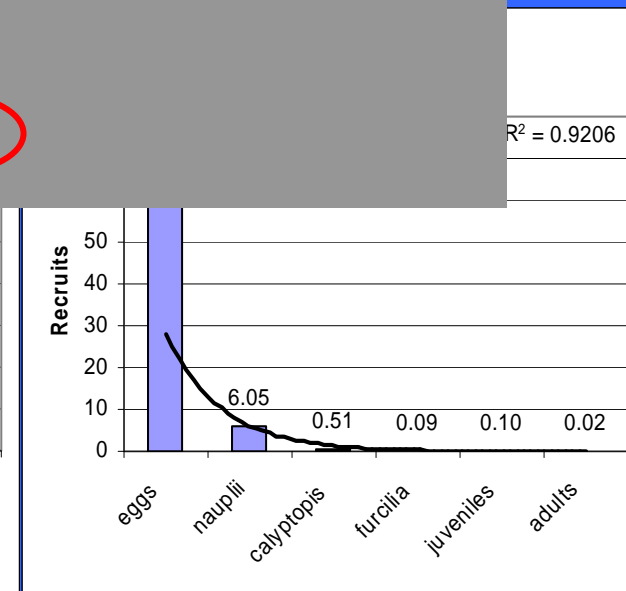
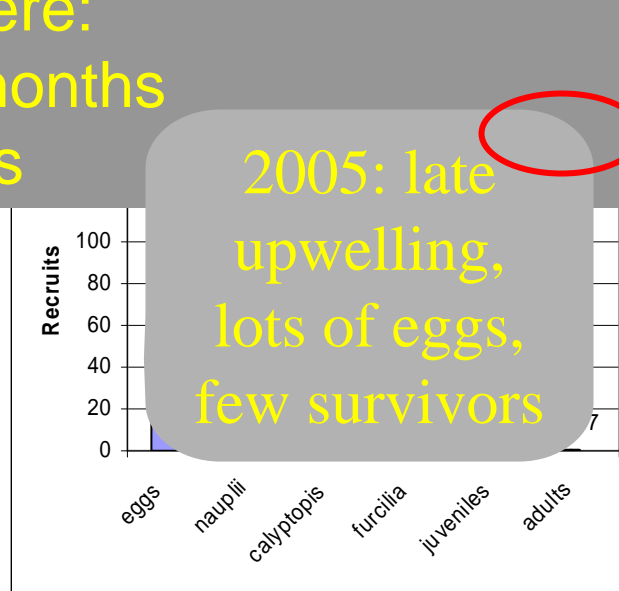
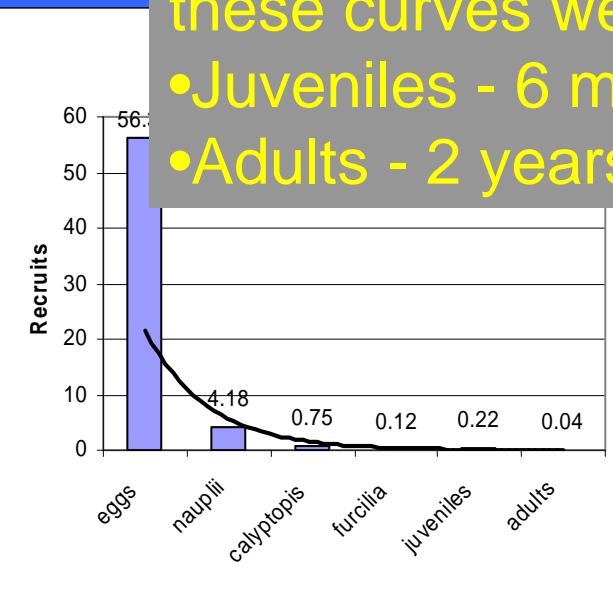
- Cohort growth rates (red) show that growth tends to slow as animals reach maturity
- IGR growth rates (gray) show range of individual variability

# Survivorship Curves



We don't have measured stage durations for juveniles and adults. The stage duration estimates that best fit these curves were:

- Juveniles - 6 months
- Adults - 2 years



# Summary & Conclusions

- Highest egg density occurred ~4 months after the spring transition (use for prediction?)
- Cohort analysis using maximum likelihood method and sufficiently short sampling interval can:
  - yield growth rates comparable to IGR experiments
  - identify some incidences of negative growth
- Biweekly sampling seems adequate to track cohorts
- Survivorship from egg to furcilia was similar among years except in 2005: delayed upwelling → delayed spawning → lower survivorship
- Survivorship curves suggest the juvenile stage lasts about 6 months and that adults live about 2 years

# Acknowledgements

- Research vessels: *R/V Sacajawea, R/V Elakha, R/V Wecoma, R/V Atlantis, R/V Frosti, R/V Miller Freeman, R/V McArthur II, R/V New Horizon*
- Funding sources: NOAA/NWFSC, ONR/NOPP, NSF/CoOP/COAST, NOAA-GLOBEC, NSF/CoOP/RISE, NOAA-SAIP
- Thanks for help with experiments: Julie Keister, Mitch Vance, Rian Hooff, Jesse Lamb, Jaime Gómez-Gutiérrez, Jennifer Menkel, Jay Peterson.



# Euphausiid Live Work Protocol

## Protocols for Measuring Molting Rate and Egg Production of Live Euphausiids



Courtesy of the Peterson Lab at Hatfield Marine Science  
Center, Newport, Oregon, USA

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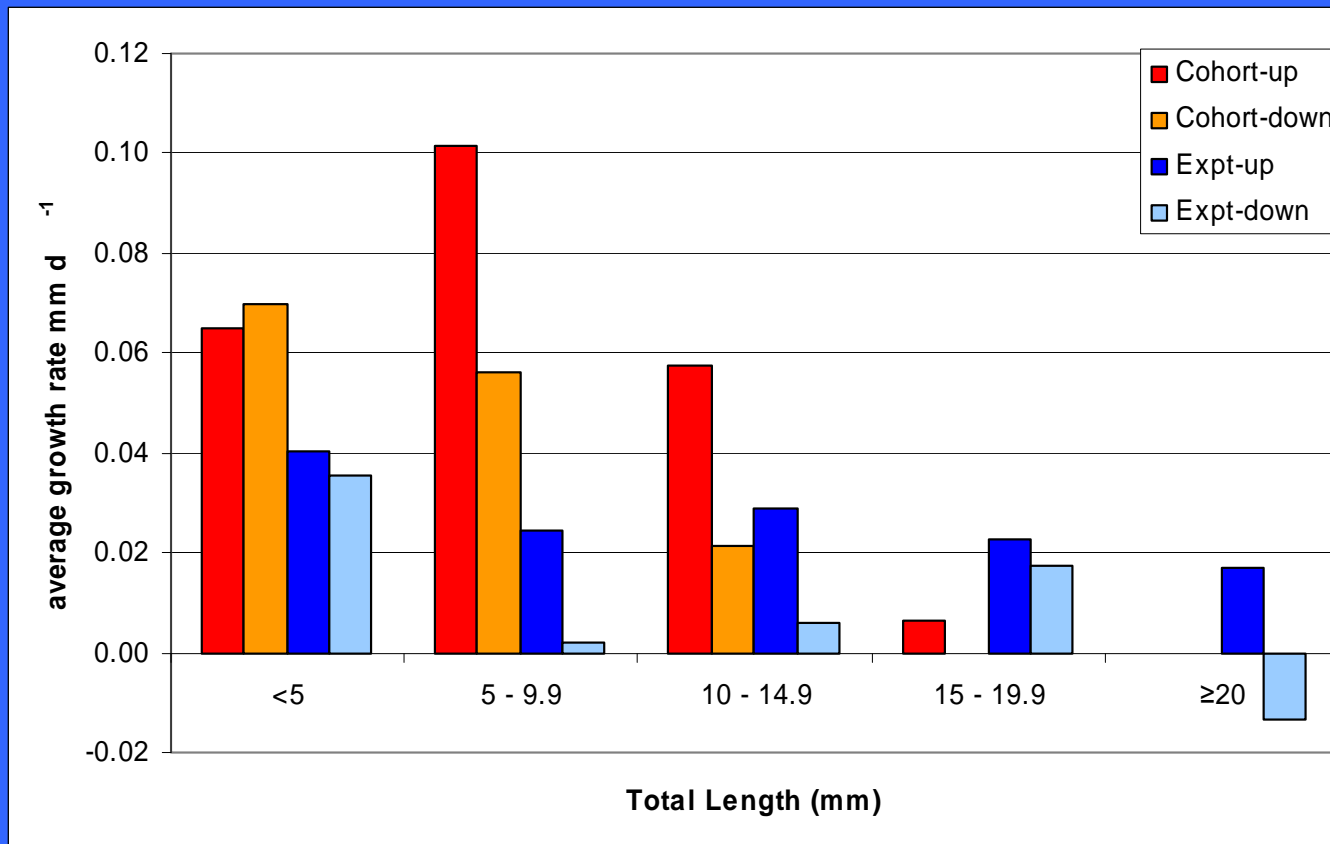
Bill Peterson  
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Newport, OR 97365  
bill.peterson@noaa.gov

- Everything you always wanted to know about working with live euphausiids!
- Available on the PICES website! ([www.pices.int](http://www.pices.int)) under the “Projects” heading

# Experimental vs. cohort growth rates

Experiment data	Cohort data
<ul style="list-style-type: none"><li>• Growth rate for each individual animal that molts</li></ul>	<ul style="list-style-type: none"><li>• Growth rate for each mode in the size frequency (1-3 growth rates for each pair of samples)</li></ul>
<ul style="list-style-type: none"><li>• Range of individual growth rates at one point in time (can't compare dates)</li></ul>	<ul style="list-style-type: none"><li>• Average growth over time interval between samples (usually 2 weeks)</li></ul>
<ul style="list-style-type: none"><li>• Individual growth rates often zero or negative</li></ul>	<ul style="list-style-type: none"><li>• Difficult to measure negative or zero growth with cohort data</li></ul>

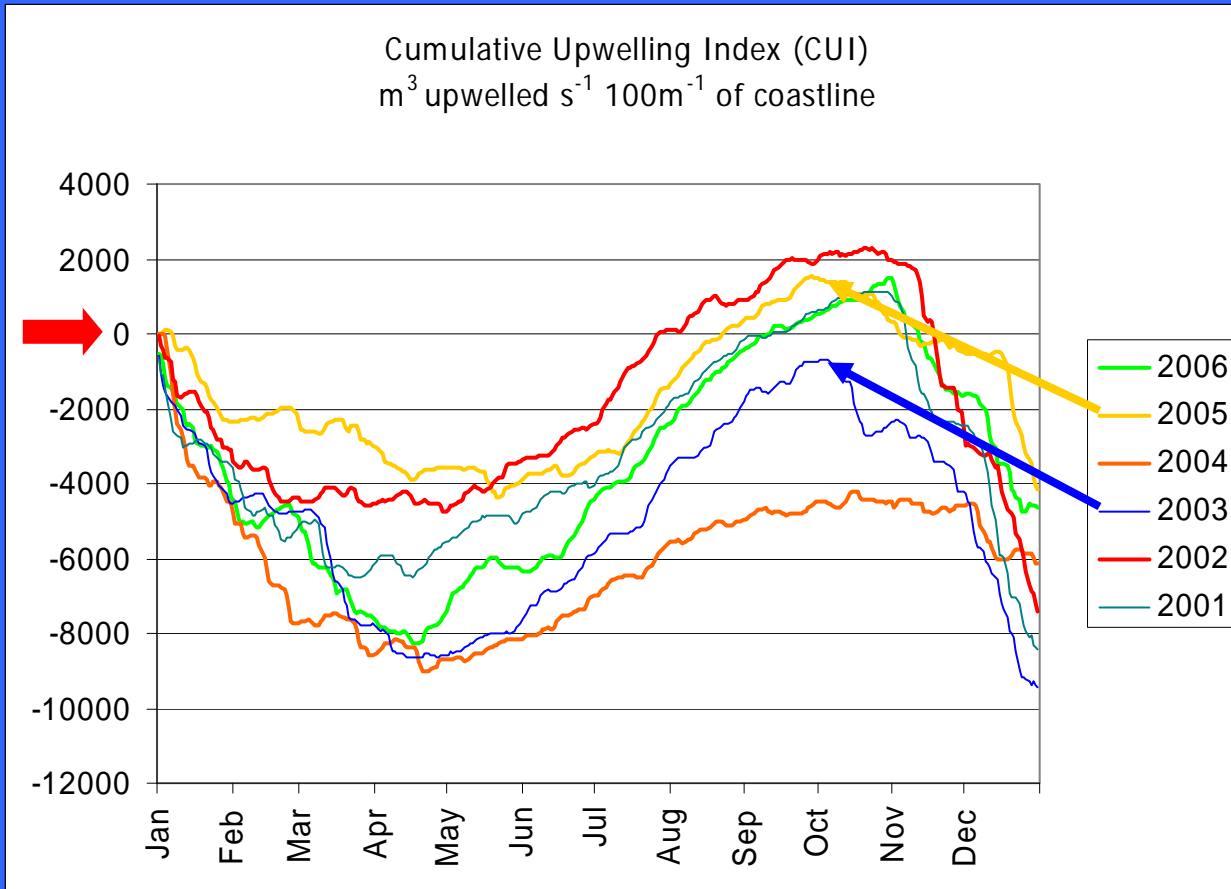
# Average growth rates by size bin



- Average individual growth rates usually lower than cohort rates (more influence from negative growth)
- Growth rates positive for small animals (<5 mm) during upwelling and downwelling

# Cumulative Upwelling Index

## 2001-2006



- CUI positive during upwelling season 2001, 2002, 2005, 2006
- Shortest upwelling seasons 2003 (5.9 mo.), and 2005 (4.2 mo.).
- Average 6.7 months of upwelling